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DYNAMIC ANALYSIS OF AN EXTRADOSED BRIDGE

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Abstract — *Aesthetic value and ability to cover large spans are the two main reasons for attracting structural engineers towards cable supported bridges in the recent years. The present study is to provide insight into how extradosed bridges behave structurally under static and dynamic loads Cable supported structures have distinctive dynamic behaviour. Extradosed bridge, which is intermediate to Girder Bridge and cable stayed bridge, owing to its shallow cables, the structure behaviour of Extradosed Bridge differs from that of cable stayed bridge. Forced vibration of structure for given Earthquake time history is governed by peak acceleration. For cable stayed structures such as Extradosed cable stayed bridge it is difficult to predict dynamic response using usual methods of dynamic analysis as applied to some other bridge structures like response spectrum analysis, accurate analysis like time history analysis is time consuming and has time and cost effects. Nonlinearities can only be considered in time history analysis. A finite element model of the extradosed bridge having same girder, geometrical dimensions and material properties as recently constructed Narmada bridge-3, Bharuch, in MIDAS-CIVIL software has been prepared. Eigen value, Response spectrum and Time history analysis have been performed with the help of MIDAS CIVIL Software. The time history analysis is done in order to achieve the seismic response under four ground motions. The study highlights the certain important parameters like deflection pattern of deck, tension generated in cables, base shear, etc. in recently constructed Narmada bridge-3 in Bharuch.*

Keywords- *Extradosed bridge, Dynamic Analysis, Static Analysis, MIDAS-CIVIL, Time History Analysis, Response Spectrum Analysis***.**

I.INTRODUCTION

The term “Extradosed” was coined by Jacques Mathivat in 1988 [1] to appropriately describe an innovative cabling concept he developed for the Arrêt-Darré Viaduct, in which external tendons were placed above the deck instead of within the cross-section as would be the case in a girder bridge. To differentiate these shallow external tendons, which define the uppermost surface of the bridge, from the stay cables found in a cable-stayed bridge, Mathivat called them “Extradosed” prestressing. Extradosed bridge is a cross between girder bridge and cable stayed bridge, adds substantial prestress to the deck because of the shallow pylon, are found to be economical for spans up to 250m [2]. There is some debate over the boundary between cable-stayed and extradosed bridges. Visually, extradosed bridges are most obviously distinguished from cable-stayed bridges by their tower height in proportion to the main span. Extradosed bridges typically have a tower height of less than one eighth of the main span. Lesser tower height results into lower inclination angle of cables connected to the deck through pylon. The reduced cable inclination in an extradosed bridge leads to an increase in the axial load in the deck and a decrease in vertical component of force at the cable anchorages. Their tension acts more to compress the bridge deck horizontally than to support it vertically. Thus, the function of the extradosed cables is also to prestress the deck, not only to provide vertical support as in a cable-stayed bridge.

With the rapid increase in span length, trend of using high strength materials have resulted in slender structures and a concern is being raised over dynamic behavior of such structures. An accurate analysis of natural frequencies is fundamental to the solution of its dynamic response due to seismic, wind and traffic loads. Dynamic response prediction of cable supported structures is main concern for many researchers because the structural design as overall economy and safety of these structures are primarily governed by earthquake load cases and combinations. The commonly used simplified methods for analysis are based on theory of dynamics pertaining to SDOF and rules of modal combinations viz. SRSS, CQC are used for MDOF systems. These combinations rules are fairly accurate and helpful since exact method such as time history analysis involves significant skills, time and cost. The response spectrum method of dynamic analysis must be used carefully. The CQC method should be used to combine modal maxima in order to minimize the introduction of avoidable errors. The increase in computational effort, as compared to the SRSS method, is small compared to the total computer time for a seismic analysis. The CQC method has a sound theoretical basis and has been accepted by most experts in earthquake engineering. The use of the absolute sum or the SRSS method for modal combination cannot be justified. The use of nonlinear spectra, which are commonly used, has very little theoretical background and should not be used for the analysis of complex three-dimensional structures. For such structures, true nonlinear time-history response should be used.

1.1. Some features of Extradosed bridge as given below:

- External appearance resembles cable-stayed bridge – but structural characteristics are comparable to those of conventional girder bridge.
- The Girder Depth are lesser than that of conventional girder bridges.
- The stay cables (prestressing tendons outside the girder) need no tension adjustment necessary for cable-stayed bridges, and can be treated as usual tendons as in girder bridges.
- The height of pylon is half as that of cable-stayed bridge and hence easier to construct.
- With small stress fluctuation under live load the anchorage method for stay cables can be same as that of tendons inside girder and thereby achieve economy.

II.MODELLING OF EXTRADOSED BRIDGE

In this research the finite element model of recently constructed Narmada bridge-3 at Bharuch is prepared in MIDAS-CIVIL to carry-out its dynamic analysis. Geometry of bridge & Pylon and Cross-section of deck are shown in ***Figure 1-3***. Finite element model is shown in ***Figure 4***. Moving load is considered as per IRC-6 2017[3]. Pylon and deck connection is considered as monolithic, fix supports are considered at pylon and hinge supports are considered at the abutment as shown in Fig.4. Girder and pylons are constructed by M55 grade of concrete and cables are made from ASTM A416-270 grade of steel. 1st cable nearer to pylon is having 0.25m diameter in all span and remaining cables are of 0.36m diameter.

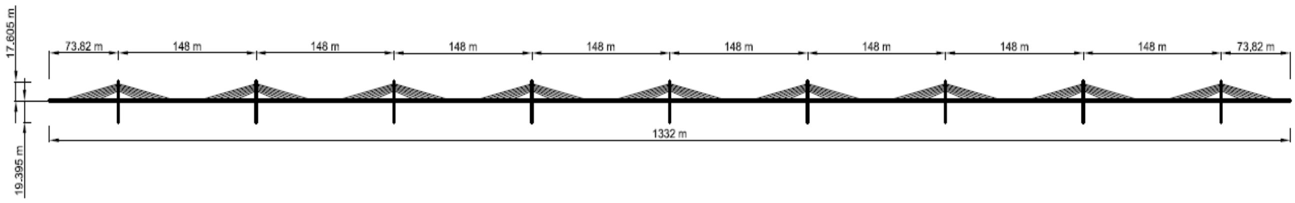
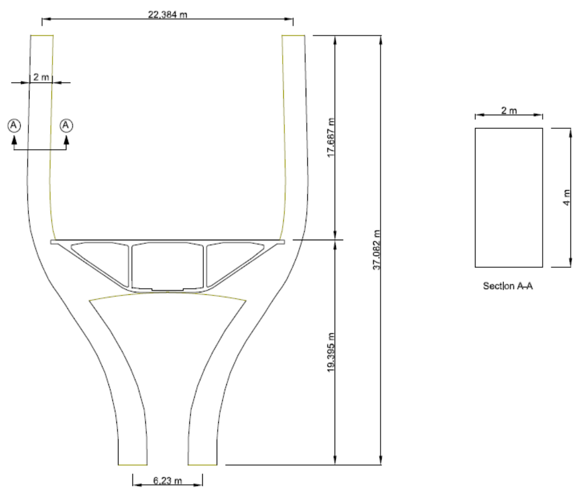


Figure 1. Geometry of an extradosed bridge



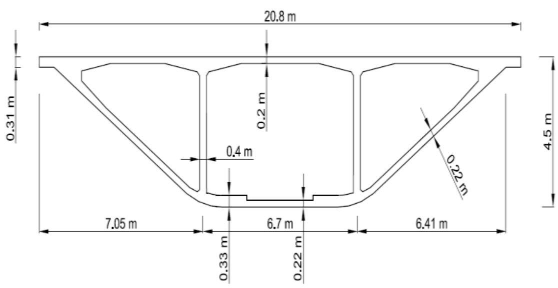


Figure 3. Cross-section of box girder

Figure 2. Pylon Geometry

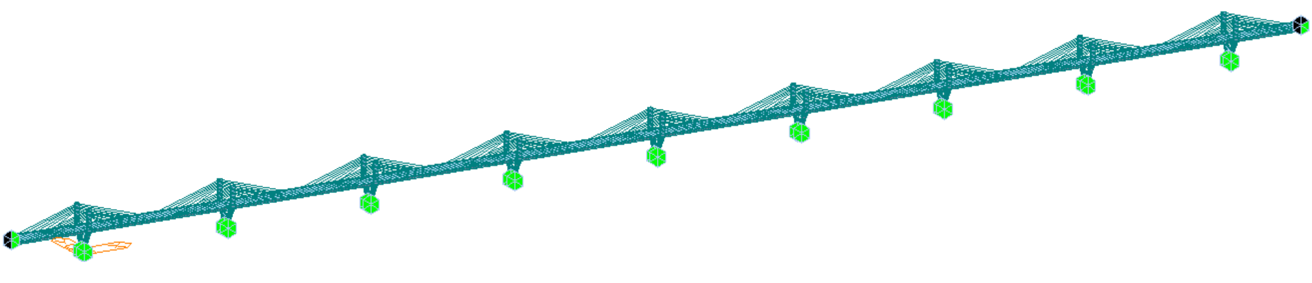
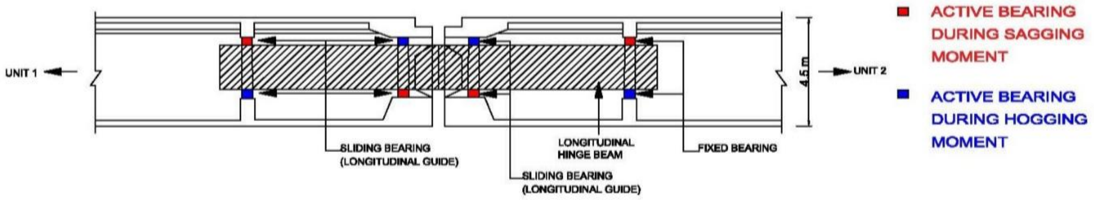


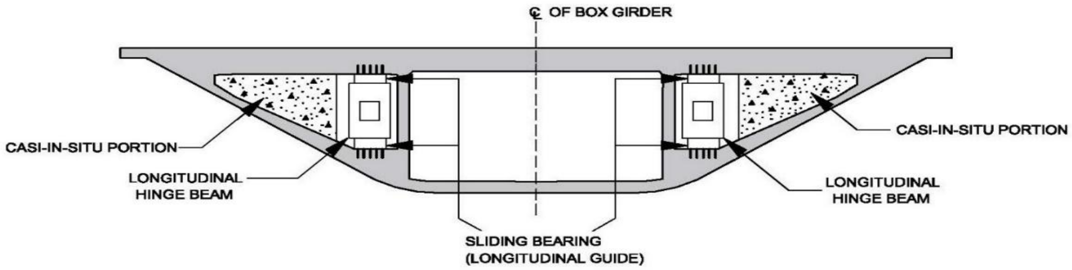
Figure 4. Finite element model of Extradosed bridge

Hinge Beam Detail at Mid-Span

In above extradosed bridge, deck is connected at the mid-span by hinge beam as shown in ***Figure 5***. Purpose of hinge beam is to reduce the moment to zero and transfer shear force from one side to other side. This is modelled as elastic link in the



(a) Longitudinal c/s of hinge beam



(b) C/S of box girder with hinge beam

Figure 5. Detail of HINGE BEAM at mid-span

finite element model. Because of provision of hinge beam, deflection of deck is equal on both sides.

III.RESULTS

3.1. Result of Eigen value analysis:

Natural frequency and time period for first 6 modes are shown in ***Table 1*** and deformation for first six modes are shown in ***Figure 6.***

Table 1. Natural frequency and time period for first 10 modes

EIGEN VALUE ANALYSIS			
Mode No	Frequency		Time Period
	(rad/sec)	(cycle/sec)	(sec)
1	2.062	0.328	3.047
2	2.130	0.339	2.950
3	2.522	0.401	2.492
4	2.661	0.424	2.361
5	2.679	0.426	2.345
6	2.707	0.431	2.321

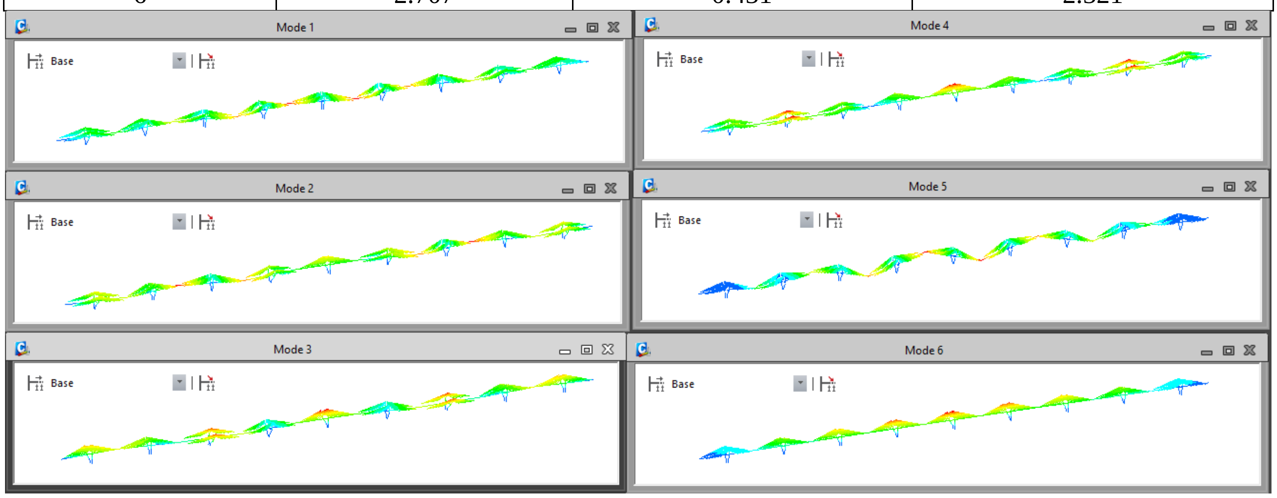


Figure 6. Mode shape for first six modes

3.2. Results of Static and Dynamic analysis:

Table 2 depicts maximum bending moment in girder in extradosed bridge due to dead load and moving load.

Table 2. Girder bending moment from static analysis

STATIC ANALYSIS MAXIMUM GIRDER BENDING MOMENT (kN*m)		
BRIDGE TYPE	Due to DL	Due to DL + ML (After cable pre-tension)
EXTRADOSED BRIDGE	73744	154467

Table 3 depicts maximum bending moment in girder for four Time history earthquake motions.

Table 3. Girder bending moment from dynamic analysis

TIME HISTORY ANALYSIS MAXIMUM GIRDER BENDING MOMENT (kN*m)		
BRIDGE TYPE	TIME HISTORY FUNCTION	GIDER BENDING MOMENT (kN*m)
EXTRADOSED BRIDGE	BHUJ (2001)	167300
	EL-CENTRO (1940)	37970
	IMPERIAL VALLEY (1940)	40550
	LOMA PRIETA (1989)	58200

3.3. Base Shear from Response Spectrum Analysis:

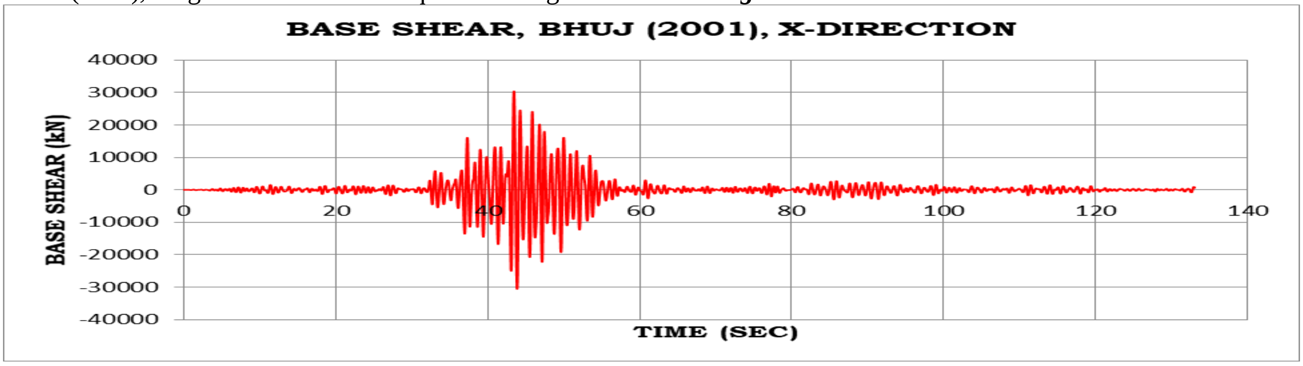
Table 4 depicts base shear from response spectrum analysis in extradosed bridge.

Table 3. base shear from response spectrum analysis

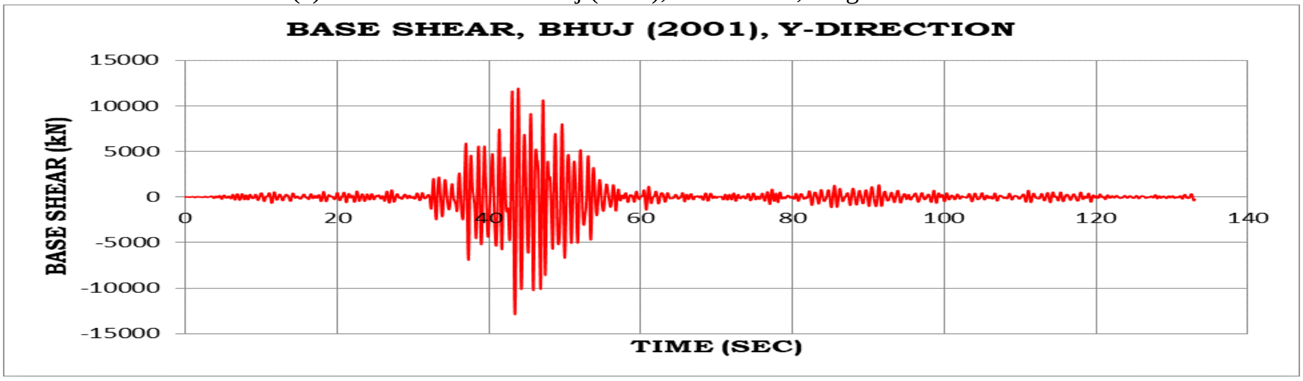
RESPONSE SPECTRUM RESULT (Base Shear)			
Load	FX (kN)	FY (kN)	FZ (kN)
Self-Weight	0	0	694693.4
Response Spectrum X	136066.417	4.688453	32.32816
Response Spectrum Y	4.897238	58311.87622	1.256712

3.4. Base Shear from Time History Analysis:

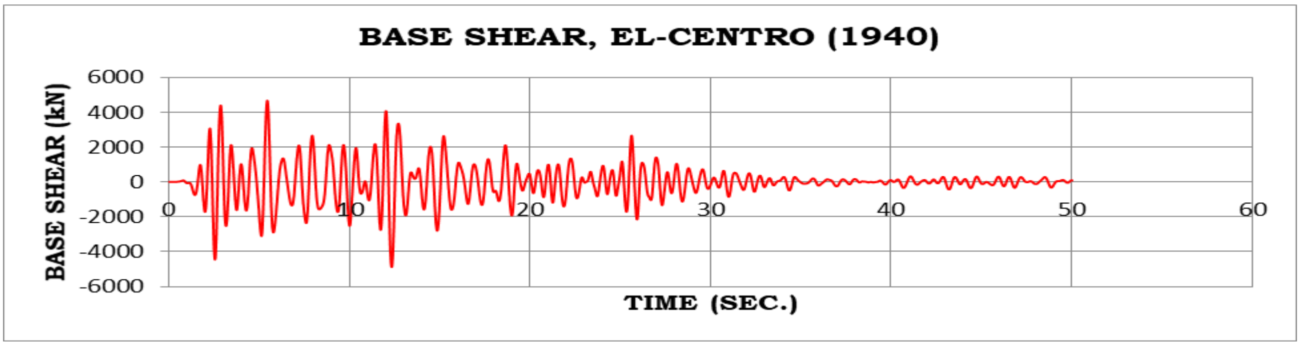
Base shear of Extradosed Bridge for (a) Bhuj (2001), X-direction, Magnitude 7.7 Mw, (b) Bhuj (2001), Y-direction, Magnitude 7.7 Mw, (c) El-Centro (1940), Magnitude 6.9 Mw, (d) Imperial valley (1940), Magnitude 6.9 Mw, (e) Loma Prieta (1989), Magnitude 6.9 Mw earthquake loadings are shown in ***Figure 7.***



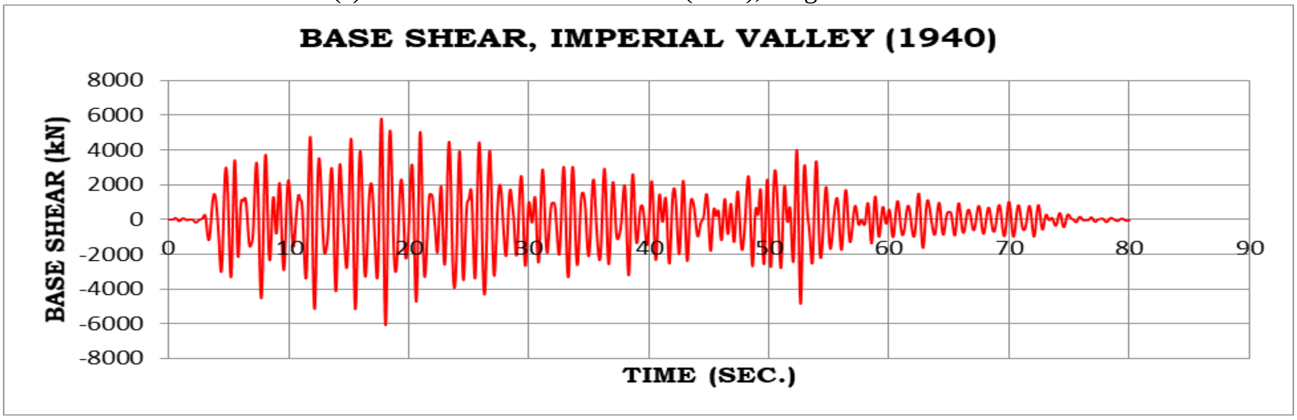
(a) Base Shear for Bhuj (2001), X-direction, Magnitude 7.7 Mw



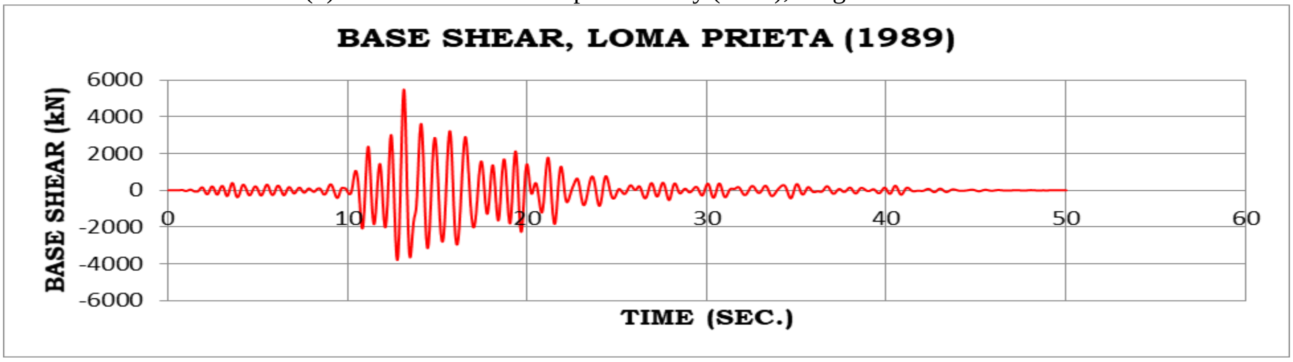
(b) Base Shear for Bhuj (2001), Y-direction, Magnitude 7.7 Mw



(c) Base Shear for El-Centro (1940), Magnitude 6.9 Mw



(d) Base Shear for Imperial valley (1940), Magnitude 6.9 Mw



(e) Base shear for Loma Prieta (1989), Magnitude 6.9 Mw

Figure 7. Base shear for (a) Bhuj (2001), X-direction, Magnitude 7.7 Mw, (b) Bhuj (2001), Y-direction, Magnitude 7.7 Mw, (c) El-Centro (1940), Magnitude 6.9 Mw, (d) Imperial valley (1940), Magnitude 6.9 Mw, (e) Loma Prieta (1989), Magnitude 6.9 Mw

Base shear due to Bhuj X-direction, Bhuj Y-direction, El-Centro, Imperial valley and Loma Prieta earthquakes are 30530 kN, 12900 kN, 4903 kN, 6069 kN and 5485 kN respectively.

***These time history graphs are taken at only one support.**

IV.CONCLUSION

The seismic response of a simplified finite element model of extradosed bridge recently constructed at Narmada river is studied under the four longitudinal component of near fault earthquake motions. From the dynamic analytical investigation of the bridge, the following conclusion may have drawn:

- From the response modal fundamental time period we can conclude that the extradosed bridge is rigid structure as compare to cable stayed and suspension bridge.
- Lower base shear response may result into economy in design and construction.
- For zones with low seismic hazard, it is advantageous to use a monolithic connection between the deck and piers because this connection improves the performance of the deck and the extradosed cables due to the frame scheme achieved.
- Extradosed bridge can be used economically for lower span up to 250m.
- In bridges with monolithic connections the height of the piers does not affect the deck under traffic loads and low earthquakes. This effect occurs because of the relative high stiffness of the deck in extradosed bridges. However, for moderate and high earthquakes, an increase on the pier's height induces a rise in the forces on the deck.
- The ideal cable forces are determined to achieve an optimal structural performance due to applied loads.

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